BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

WORKSHOP REPORT
REGULATION 13, CLIMATE POLLUTANTS: RULE 5, PETROLEUM REFINERY HYDROGEN SYSTEMS

Source: https://chemicalparks.eu/news/2015-4-17-air-liquide-starts-up-a-large-hydrogen-production-unit-in-germany

January 2020

Prepared By

William Thomas Saltz
Senior Air Quality Specialist

(This page was intentionally left blank)

ACKNOWLEDGEMENTS

District staff members who also greatly contributed to the development of this report and draft rule proposal:

Jerry Bovee, Manager: Meteorology and Measurements Division
Brian Butler, Senior Air Quality Engineer: Community Engagement and Policy Division
Linda Duca, Supervising Air Quality Specialist: Compliance and Enforcement Division
Victor Douglas, Manager: Community Engagement and Policy Division
Madeline Stone, Assistant Counsel: Legal Division
Art Valla, Principal Engineer: Engineering Division

WORKSHOP REPORT

Regulation 13, Rule 5: Petroleum Refinery Hydrogen Systems

TABLE OF CONTENTS

I. INTRODUCTION

This Workshop Report provides preliminary information regarding development of a new rule by the staff of the Bay Area Air Quality Management District (BAAQMD or Air District), draft Regulation 13: Climate Pollutants, Rule 5: Petroleum Refinery Hydrogen Systems (Rule 13-5). Draft Rule 13-5 would limit vented emissions of methane and organic compounds from petroleum refineries' hydrogen production, hydrogen carrying systems and hydrogen end users such as process units.

The State of California has made the reduction of greenhouse gas emissions a priority. In September 2016, Governor Brown signed Senate Bill 32 (Chapter 249, Statutes of 2016), which mandated a greenhouse gas emissions reduction target of 40 percent below 1990 emission levels by 2030. Senate Bill 605 (Chapter 523, Statutes of 2014) requires the California Air Resources Board to develop a plan to reduce emissions of short-lived climate pollutants, and Senate Bill 1383 (Chapter 249, Statutes of 2016) requires the California Air Resources Board to approve and implement a plan by January 2018 to achieve these reductions. Senate Bill 1383 also sets a target for the reduction of methane emissions of 40 percent below 2013 levels by 2030. Pursuant to Senate Bill 605 and Senate Bill 1383, the California Air Resources Board subsequently developed the short-lived climate pollutant Reduction Strategy, adopted in March 2017.

The Air District has a policy goal of reducing Bay Area greenhouse gas emissions to 40 percent below 1990 levels by 2030, and 80 percent below 1990 levels by 2050. Methane is a potent and short-lived climate pollutant; its global warming potential is 86 times greater than that of carbon dioxide (CO_2), when compared on a 20-year time horizon.[1,2] Methane represents the second largest emissions of greenhouse gases in the region, after CO_2. In 2015, all methane sources located within the Air District emitted an estimated 10 million metric tons of CO_2 equivalent, about 10 percent of the Bay Area's greenhouse gas inventory. The sources of methane emissions include stationary sources such as landfills, wastewater treatment facilities, refineries, natural gas production and distribution systems; mobile sources such as cars and trucks; and natural sources such as wetlands. Reducing emissions of short-lived climate pollutants, including methane, can have a dramatic effect on climate change in the near term as their atmospheric lifetime is much less than longer-lived greenhouse gasses, such as CO_2. These climate pollutants are estimated to be responsible for roughly 40 percent of the current net climate forcing effect. Given the importance of controlling methane, the Air District has developed a comprehensive Basin-wide Methane Strategy as part of its 2017 Clean Air Plan. The Methane Strategy is an agency-wide effort to better quantify and reduce the region's methane emissions. Draft Rule 13-5 would be one of the first rules developed as part of this Strategy. Other source-specific methane rules are under development to address emissions from specific operations.

Draft Rule 13-5 would address one of the largest sources of methane emissions from Bay Area petroleum refineries. There are currently nine permitted hydrogen plants associated with five petroleum refinery hydrogen systems within the Air District's jurisdiction. All but one of the plants are components of refinery-wide hydrogen systems. Petroleum refinery hydrogen systems vent

[1] Based on the 20-year GWP reported for methane in the Intergovernmental Panel on Climate Change Fifth Assessment Report.

[2] Unless otherwise stated, this report uses the 20-year global warming potential (GWP) of 86 when calculating the carbon dioxide equivalent of methane emissions since the emission reduction actions being considered are within that time frame.

hydrogen gas under a variety of circumstances including startups, shutdowns, malfunctions and upsets. Staff continues to determine the extent of methane emissions; however, initial data gathering indicates that emissions from all petroleum hydrogen system sources average approximately 1,200 tons per year (TPY) for calendar years 2016, 2017 and 2018. The intent of Draft Rule 13-5 is to minimize methane and organic compound emissions normally vented from the atmospheric vents located at petroleum refinery hydrogen systems during startups, shutdowns, malfunctions and upsets. The reduction in methane and organic compound emissions will be achieved by providing hydrogen system operators the flexibility to either capture and reuse methane-containing hydrogen gas for incorporation into refinery gas fuel systems or to control hydrocarbon emissions with abatement technology. Capturing hydrogen gases and reusing them in the refinery system could control methane emissions up to 100 percent unless captured gases are routed to an abatement device. Hydrogen gases routed directly to an abatement device would have to meet a 98 percent control efficiency standard. Rule 13-5 will include a provision that exempts vented emissions of pure hydrogen gas, defined as a gas stream containing at least 98 percent hydrogen.

This report discusses the purpose of draft Rule 13-5, its emission standards, and how compliance with the rule would be determined and monitored. Staff continues to gather information to estimate emission reductions and associated costs.

The Air District published this report to explain draft Rule 13-5 to members of the public, affected industry, and other interested parties. Draft regulatory language for Rule 13-5 was developed and is available for review as well. Staff welcomes input from any stakeholders. The Air District plans to hold one public workshop during the month of January to discuss the Draft Rule and invite stakeholder input on all aspects of the draft rule. Feedback can be provided in person at the workshop or can be submitted to the Air District (verbally or in writing) during the comment period. Following the workshop, in the final phase of this rule development effort, staff will prepare a Public Hearing package – containing the proposed regulatory version of Rule 13-5, a draft staff report, a socioeconomic analysis, and a California Environmental Quality Act environmental analysis, if necessary – that will be presented to the Air District's Board of Directors for its consideration.

II. BACKGROUND

A. Refinery Hydrogen Use

Hydrogen, the most abundant chemical substance in the universe, is a colorless, odorless, tasteless and non-toxic gas at standard temperature and pressure. When ignited, hydrogen reacts with oxygen in the air to create heat that in turn can be used for energy. Thus, hydrogen is considered to be an energy carrier and is used in an extensive range of industrial applications.[a] While this workshop report references the production and consumption of hydrogen in petroleum refineries, the purpose of this rule is to reduce the emissions of methane gas that is inherently a component of the hydrogen gas stream vented to atmosphere during certain operational conditions. Reducing hydrogen gas emissions results in the reduction of methane emissions.

In the petroleum refining industry, hydrogen is used to convert crude oil into refined fuels such as gasoline and diesel. Hydrogen is also consumed in desulfurization units to remove contaminants from fuels and feedstocks. Additionally, hydrogen is used in the refinery fuel system. As petroleum refinery product specifications become more stringent to meet environmental requirements, refinery demand for hydrogen has continually increased to supply the refinery hydrogen consumers (process units). The two primary hydrogen consumers in Bay Area petroleum refineries are processes known as hydrotreating and hydrocracking.

1. Hydrotreating

Hydrotreating is a process whereby hydrogen is added to a hydrocarbon gas (often referred to as a feedstock) stream over a bed of catalyst typically containing molybdenum with nickel or cobalt, at an intermediate temperature and pressure, as well as other process-specific operating conditions. The purpose of hydrotreating is to remove sulfur and other undesirable compounds, such as unsaturated hydrocarbons and nitrogen, from the hydrocarbon stream.[b] Sulfur will poison (shorten the lifespan of) catalysts used in hydrocarbon processing applications so refineries take great measures to protect catalysts to extend their operating longevity as long as possible. During hydrotreating, sulfur compounds react with hydrogen to form hydrogen sulfide, while nitrogen compounds react to form ammonia. Aromatics and olefins are saturated by the hydrogen and lighter products are created. The final result of the hydrotreating process is the elimination of sulfur and other contaminants from the original feedstock.

2. Hydrocracking

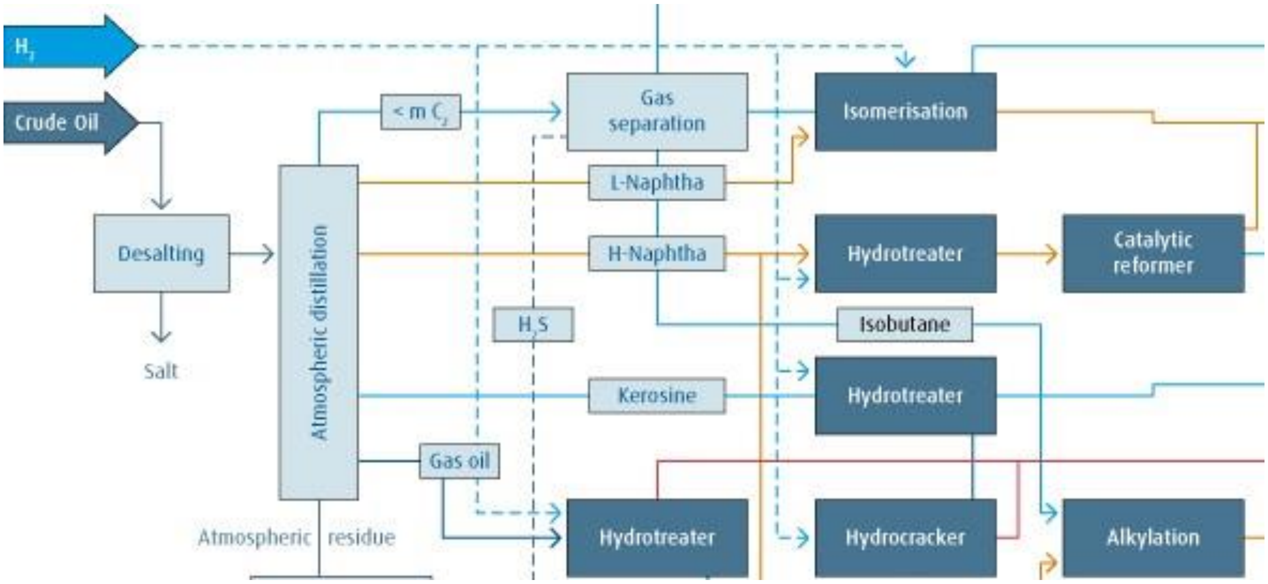
Hydrocracking is a refinery process that produces lighter molecules with higher value for diesel, aviation fuel and petrol fuel from long-chain hydrocarbons. In this process, heavy gas oils, heavy residues or similar boiling-range heavy distillates are reacted with hydrogen in the presence of a catalyst at high temperature and pressure. The heavy feedstocks are converted (or “cracked”) into light or middle distillate products – for example, naphtha, kerosene and diesel – or base stocks for lubricants. For some refineries, the hydrocracker unit is the top hydrogen consumer. Hydrogen is the key component that enables the hydrocracking process to reduce the product boiling range appreciably by converting the majority of the feedstock to lower-boiling, more desirable products.[c]

B. Refinery Hydrogen Production

Refinery Hydrogen Source

With the increase in demand for hydrogen use at petroleum refineries, producing their own, instead of purchasing it, is economically advantageous for refineries. In some instances, refineries pay an independent, third party to produce hydrogen in a facility that is either contiguous to or located within the refinery property. The production, distribution and use of hydrogen within petroleum refineries is all part of an integrated system that is referred to as a “Refinery Hydrogen System” for the purposes of this workshop report and the development of draft Rule 13-5. A refinery hydrogen system consists of one or more hydrogen plants, the distribution network, the processes (or “consumers” covered in the previous section of this workshop report) that use hydrogen and a secondary method of producing hydrogen known as “catalytic reforming” or “naphtha reforming units”. Hydrogen is produced in a process unit most often referred to as a “hydrogen plant.” The heart of the plant consists of a steam methane reformer and additional hydrogen purification steps that are integrated with all the processes in need of hydrogen throughout the refinery.

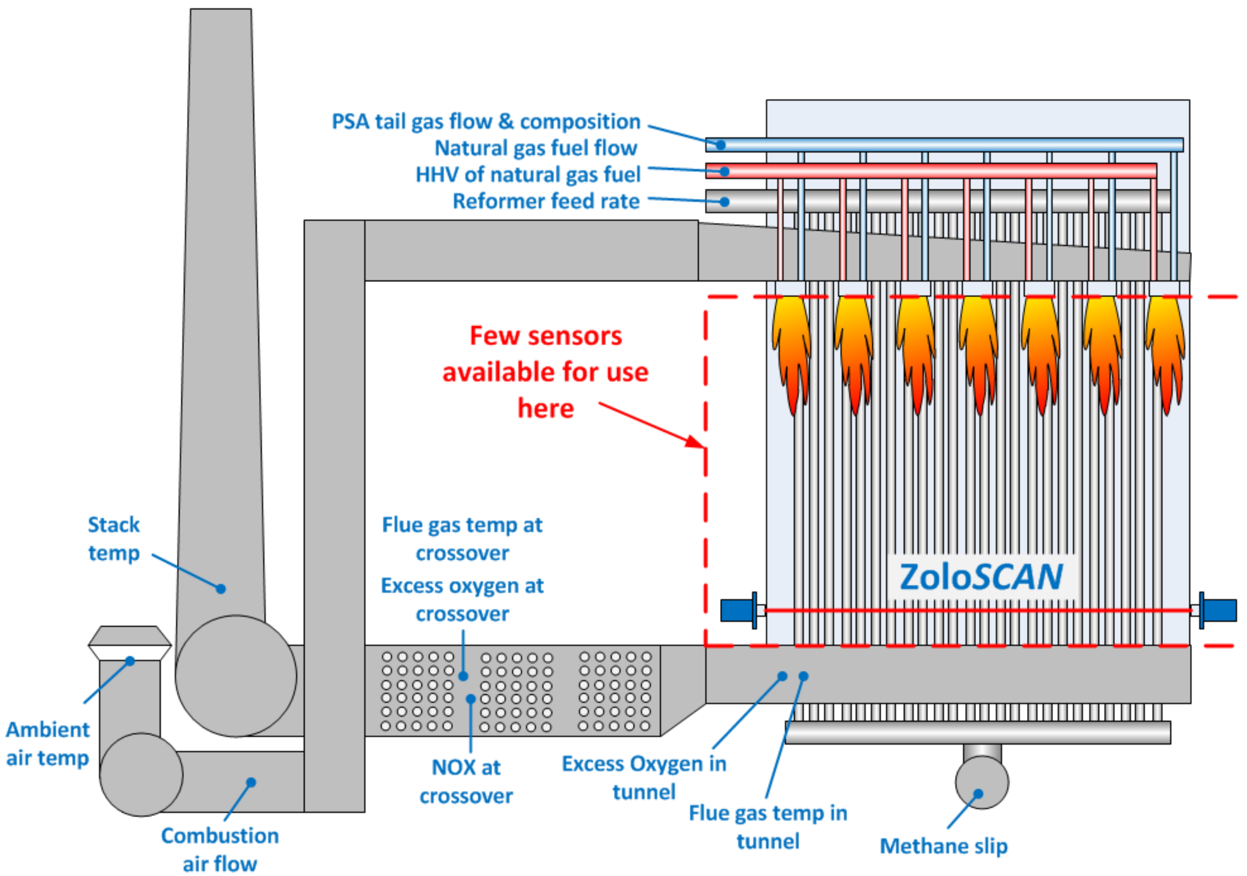
Figure 1: Basic diagram of hydrogen distribution to petroleum refinery consumers



Source:https://www.linde-gas.com/en/processes/petrochemical-processing-and-refining/hydrogen_applications_refineries/index.html

Hydrogen production generally includes four steps: 1) the purification of the feed gas (usually natural gas or refinery fuel gas, although other gases may be used depending on economic conditions); 2) reforming reaction in the steam methane reformer box to convert most of the methane gas to hydrogen; 3) temperature shift reaction to convert some of the remaining methane to hydrogen; and 4) final product purification step.

Figure 2: Depiction of the interior of a typical steam methane reformer

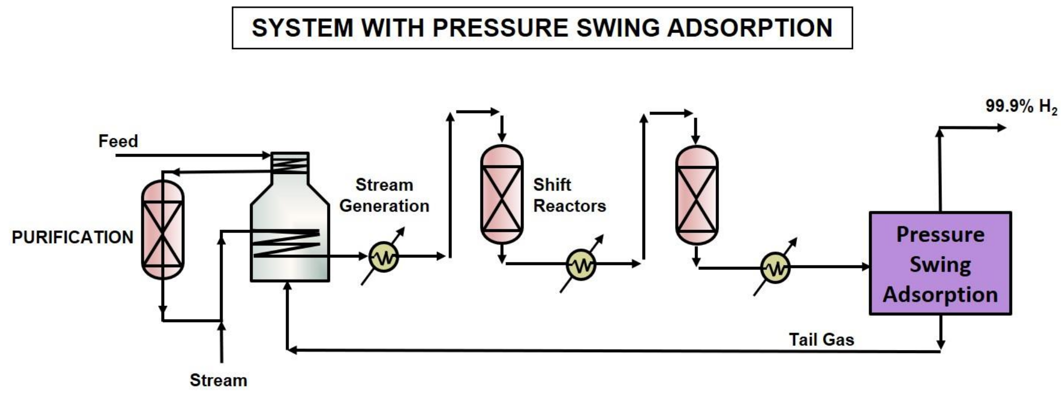


Source: https://imgbin.com/png/YMAAMgps/furnace-methane-reformer-steam-reforming-catalytic-reforming-natural-gas-png

Refinery hydrogen plants consist of two types, those with pressure swing adsorption and those without. Pressure swing absorption produces a purer form of hydrogen required by certain refinery applications.

Prior to distributing hydrogen into the refinery hydrogen network, most hydrogen plants use a pressure swing adsorption process for the final purification step at the back end of the system to produce hydrogen with a minimum 99.99 percent concentration in the gas stream. A byproduct of the pressure swing adsorption process, referred to as “tail gas” is routed to the steam methane reformer as fuel and can contain 15-20 percent methane.

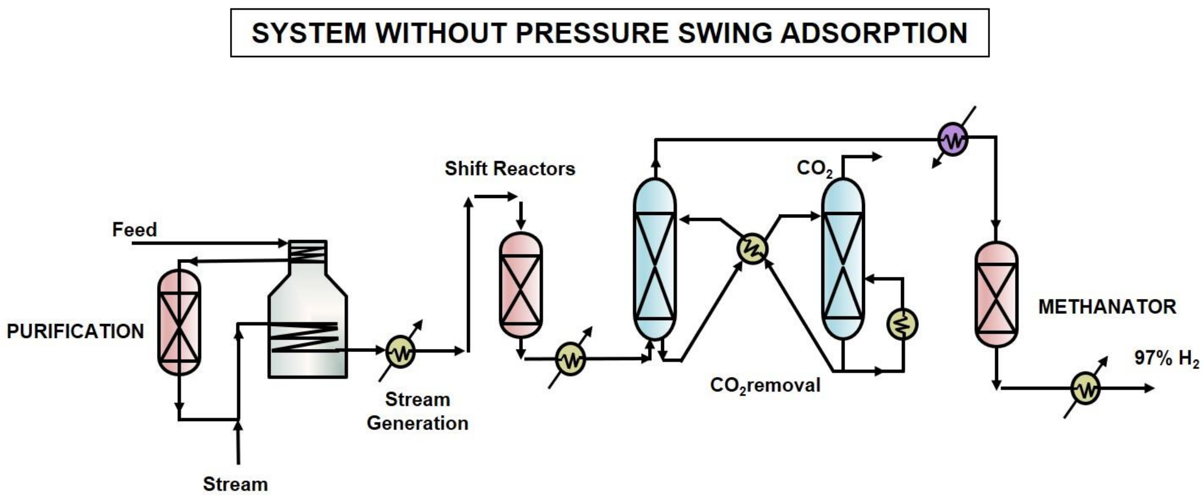
Figure 3: Flow diagram of a hydrogen plant with pressure swing adsorption purification



Source: Air District Staff

By contrast, a hydrogen plant that does not use a pressure swing adsorption produces a less pure hydrogen stream that contains a higher amount of methane – generally between four and six percent.

Figure 4: Diagram of a hydrogen plant without pressure swing absorption purification



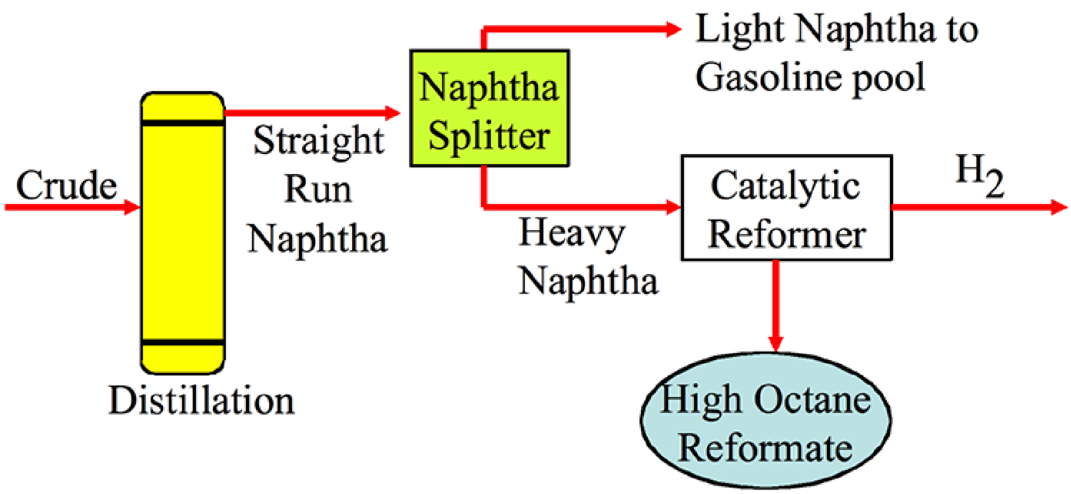
Source: Air District Staff

Methane emissions occur when impure hydrogen gases are purposely vented from atmospheric vents (sometimes referred to as process vents) located at various junctures throughout the hydrogen system. Generally, most hydrogen atmospheric venting occurs within the hydrogen plant, compared to the amount of venting that occurs within the remainder of the hydrogen system. Hydrogen gas is not vented to atmosphere as a matter of course, it is only vented when necessary, usually for safety-related reasons such as refinery startups, shutdowns, malfunctions, trips or process upsets.[d]

Catalytic Reforming Units

Catalytic reforming units, more commonly referred to as naphtha reforming units, function as part of a petroleum refinery's hydrogen system as a secondary method of producing hydrogen. The primary purpose of the catalytic reforming process is to convert heavy naphthas distilled from crude oil into lighter components. During this chemical process, heavy naphthas that typically have low octane ratings are reformed into lighter naphthas with higher octane ratings. Often referred to as reformates, light naphthas are a product used as blending stocks for high-octane gasoline. As a byproduct of the naphtha reforming process, hydrogen is produced and is used in nearby hydrogen consumers. Although vented naphtha reforming unit gases contain a greater concentration of methane than that of hydrogen gas vented by hydrogen plants, the relative amount of methane mass emissions from naphtha reforming units are less than the amount emitted from hydrogen plants due to the difference in volumes and flowrates.

Figure 5: Flow diagram schematic of a refinery catalytic reforming process



Source: Dr. Semih Eser via https://www.e-education.psu.edu/fsc432/content/catalytic-reforming

C. Regulatory History

1. Air District Rules/Regulations

Currently, the Air District does not have a rule that specifically addresses vented methane emissions from refinery hydrogen systems including hydrogen plants, hydrogen distribution, hydrogen consumers and catalytic reformers. Air District Regulation 8, Rule 18: Equipment Leaks limits the emissions of total organic compounds from leaks from equipment such as valves, connectors, pumps, compressors, pressure relief devices, diaphragms, hatches, sight-glasses, fittings, sampling ports, meters, pipes, and vessels located at petroleum refineries, chemical plants, bulk plants and bulk terminals. By definition, total organic compounds include methane.[e]

2. Rules from other Air Districts

The South Coast Air Quality Management District has a hydrogen plant rule, Rule 1189: Emissions from Hydrogen Plant Process Vents, that regulates volatile organic compounds from hydrogen plant process vents as a method of limiting methanol emissions but does not specifically address methane or any other greenhouse gas emissions.[f] No California air districts currently regulate methane emissions from hydrogen plant operations via source-specific rules.

3. State Regulations

At the State level, the Mandatory Reporting of Greenhouse Gas Emissions program requires petroleum refineries to report annual greenhouse gas emissions generated by various refining operations to the California Air Resources Board.[g] Although California regulates greenhouse gas emissions from large facilities such as petroleum refineries via California's Cap-and-Trade program, methane-specific emission reductions are not required.[h]

4. Federal Regulations

Other than Title V operating permit requirements addressed above, there are no substantive federal air quality regulations that address methane emissions from petroleum refining hydrogen systems. Refineries report annual greenhouse gas emissions to the United States Environmental Protection Agency as required by the Greenhouse Gas Reporting Program.[i]

5. Other Air District Rule Development Efforts

Concurrent with the development of Rule 13-5, the Air District is also developing Regulation 13, Rule 2: Material Handling; Regulation 13, Rule 3: Composting; and Regulation 13, Rule 4: Sewage Treatment Plants and Anaerobic Digesters to minimize emissions of greenhouse gases and volatile organic compounds from anaerobic digesters and sewage treatment plants. Draft Rule 13-5 would implement portions of the 2017 Clean Air Plan and is intended to create a consistent regulatory framework for these operations. In addition, the Air District is working on amendments to Regulation 8, Rule 34: Solid Waste Disposal Sites to better address emissions of methane and non-methane volatile organic compounds from solid waste disposal facilities and improve compliance and permitting for these facilities.

III. TECHNICAL REVIEW

A. Emissions

The Air District does not yet have a verified, complete emissions inventory for methane emissions from the venting of hydrogen gas produced, distributed and used in petroleum refinery hydrogen systems. Staff is in the process of gathering data to compile a methane emissions inventory from all petroleum refinery hydrogen system components that vent hydrogen, including hydrogen plants, catalytic reformers and hydrogen consumers. Based on initial mass emissions data provided to staff from the refineries and two independent, third-party operators, thus far, it appears the average total yearly methane emissions for each of the past three calendar years (2016, 2017 and 2018) from all hydrogen systems is approximately 1,200 TPY. Staff continues to collect and evaluate methane emissions flow rates and mass emissions information for all petroleum refinery hydrogen systems. Additionally, staff is reviewing reported emissions from hydrogen system operators and the emissions data measured from aerial flights conducted by NASA JPL to ensure consistency.[j] In addition, staff is reviewing mass methane emissions reported by the hydrogen system operators and calculated mass emissions extrapolated from data collected during a recent investigation conducted by the Air District regarding petroleum refineries compliance with Regulation 8, Rule 2: Miscellaneous Operations to ensure consistency and accuracy.

B. Emission Control Methods

Because vented methane emissions from petroleum refinery hydrogen systems are not currently subject to emission limits, such emissions are usually uncontrolled unless the methane is a constituent of a gaseous stream that includes other air pollutants, such as volatile organic compounds, subject to emission limit requirements of another regulation. However, not all volatile organic compound abatement technology will capture or control methane emissions. For example, activated carbon is commonly used to extract volatile organic compounds from gaseous streams via an adsorption process that traps volatile organic compound molecules onto the surface of carbon molecules while the remainder of the gaseous stream continues to flow through the carbon bed. However, methane is not typically captured by activated carbon so it flows through unabated.

One example of control technology that reduces methane as a co-benefit of reducing other air contaminants is a flare. Flares are used as a safety device, not as control devices to reduce refinery gases that often may include a mixture of gases including volatile organic compounds, toxic air contaminants, oxides of nitrogen, sulfur oxides and methane. Nevertheless, one Bay Area refinery and one third-party operator use flares dedicated specifically to control hydrogen gas emissions, and thus, methane emissions. These particular types of flares destroy methane emissions at a minimum 98 percent control efficiency.

Thermal oxidizers are another example of control technology used to thermally destroy industrial vapor streams. They are commonly used in refineries and chemical plants to control hydrocarbon-based vapors. Typically, thermal oxidizers are available in four different types depending on a variety of factors. They include direct-fired, recuperative, catalytic and regenerative thermal oxidizers.

A third method of controlling methane emissions already employed at two local refineries is the use of a closed loop system that captures hydrogen system gas streams, normally vented at other refineries, and reintroduces the stream into the refinery's fuel gas system. Only a small amount of the captured methane gas is vented to atmosphere because hydrogen system gas can only be sent to the flare for safety-related reasons such as malfunctions, unplanned shutdowns, upsets and trips in the refinery system. Less than two percent of flare header gas sent to the flare for thermal destruction is emitted to the atmosphere post combustion. Flare headers, a collection system for refinery waste vapor streams, contains a mixture of refinery gases, including hydrogen system gas.

Although not technically considered a control technology, use of pressure swing adsorption can significantly reduce methane emissions. Pressure swing adsorption purification is a method of separating one or more gas species from a gaseous stream containing additional (desirable) gas species. As mentioned earlier in this report, pressure swing adsorption is used in hydrogen production as a final purification step to separate hydrogen gas molecules from other (impure) gas molecules, such as methane. Under pressure, an adsorbent material targets gas with dissimilar adsorption properties as an effective way of extracting very pure hydrogen.[k] As depicted in Figure 3 of this report, tail-gas, a byproduct of the pressure swing adsorption process containing the removed impurities, can then be sent back to the steam methane reformer as fuel for the steam methane reforming process. Normally, pressure swing adsorption purification removes methane molecules from the hydrogen gas stream only at the back end of the steam methane reforming process unit. Atmospheric venting prior to the pressure swing adsorption step contains methane and other air contaminants.

Figure 6: Image of several tanks containing the adsorbent material that comprise part of a pressure swing adsorption system

Source: https://www.petrosadid.com/fixed_equipment/process_package/pressure_swing_adsorption.php

IV. DRAFT RULE

A. Purpose

Draft Rule 13-5 is being developed to ensure that vented methane and organic compound emissions including volatile organic compounds and toxic air contaminants are minimized from petroleum refinery hydrogen systems. Methane and organic compound emissions would therefore be minimized during the production of hydrogen, the distribution of hydrogen and the consuming of hydrogen at various refinery process units.

B. Applicability

Draft Rule 13-5 would apply to petroleum refinery hydrogen systems, including third-party operators that produce hydrogen in hydrogen plants integrated into petroleum refinery hydrogen systems.

C. Exemptions

The requirements in draft Rule 13-5 are not intended to apply to methane emissions already subject to other Air District rules. For example, methane leaks from refinery equipment are already subject to the requirements in Rule 8-18: Equipment Leaks. Rule 13-5 also would exempt hydrogen emissions that meet the purity criterion.

D. Definitions

Because Rule 13-5 is a new rule that would limit emissions of a new contaminant, definitions are provided to clarify exemptions, standards and administrative requirements including monitoring and recordkeeping. The key definitions are new terms such as atmospheric vent, atmospheric venting, complete capture, hydrogen plant and petroleum refinery hydrogen system. These and other definitions referenced from existing regulations help to distinguish the applicability of this Rule from the applicability of hydrogen gas emissions to other Air District Rules such as Regulation 8, Rule 18: Equipment Leaks; and Regulation 8, Rule 28: Episodic Releases from Pressure Relief Devices at Petroleum Refineries and Chemical Plants.

E. Standards

Draft Rule 13-5 would address methane and organic compound emissions from refinery hydrogen systems as follows:

Section 13-5-301, Complete Capture Requirements for Existing Petroleum Refinery Hydrogen Systems, would prohibit the owner or operator of petroleum refinery hydrogen plants from venting to atmosphere hydrogen waste streams containing less than 98% hydrogen. All petroleum refinery hydrogen gas waste streams must be controlled to at least 98% capture efficiency.

Section 13-5-302, Complete Capture Requirements for New Petroleum Refinery Hydrogen Plants, would prohibit the owner or operator of petroleum refinery hydrogen plants from venting to atmosphere hydrogen waste streams containing less than 99.99% hydrogen.

F. Administrative Requirements

The draft Rule includes a requirement for the operator of an existing petroleum refinery hydrogen system to notify the Air District of atmospheric venting occurrences from abatement devices within three business days if control efficiencies are below 98 percent or if the mass emissions of methane or organic compounds are greater than 10 pounds per day from each atmospheric vent. Within 10 business days, a report of the event shall be submitted and shall include all parameters relating to emissions as well as the make and model of the control device. New petroleum refinery hydrogen plants will be subject to the same notification requirements when hydrogen gas with a purity less than 99.99 percent is vented to atmosphere without the 10-pound per day exception.

Draft Rule 13-5 also includes a capture requirement for petroleum refinery hydrogen systems to use a gas recovery system to limit emissions of hydrogen gas. Gas recovery is the preferred method to limit hydrogen gas emissions because gas recovery is more energy efficient and results in less greenhouse gas emissions compared to the use of hydrogen gas emission control technologies. The owner or operator of a petroleum refinery hydrogen plant would have a total of no more than four years to design, purchase, install and acquire an Air District Permit to Operate for a hydrogen gas recovery system.

Draft Rule 13-5 includes a control requirement for petroleum refinery hydrogen systems that do not completely capture hydrogen gas emissions. Hydrogen gas that is not captured must be abated with control technology having a capture and control efficiency of least 98 percent, by weight. This standard is based on the federal requirement of a minimum 98 percent control for refinery flares. The owner or operator of a petroleum refinery hydrogen plant would have a total of no more than four years to design, purchase, install and acquire an Air District Permit to Operate for a hydrogen gas abatement system.

G. Monitoring and Records

The operator of a petroleum refinery hydrogen system subject to the proposed rule must monitor and record all parameters necessary to demonstrate compliance with the provisions set forth in the standards section of draft Rule 13-5. Atmospheric venting of hydrogen gas from a pressure swing absorption vent is exempt from the standards in Section 300 of Rule 13-5 provided the owner or operator keeps daily records of hydrogen purity to ensure they qualify for the limited exemption in Section 13-5-104.

H. Manual of Procedures

The Manual of Procedures Section in Rule 13-5 requires petroleum refinery hydrogen system owners or operators to submit methods for approval to determine compliance with control efficiency requirements in Section 13-5-402, to determine mass emissions for applicability with Section 13-5-202 or to determine hydrogen purity to qualify for the limited exemption in Section 13-5-104.

V. RULE DEVELOPMENT / PUBLIC PARTICIPATION PROCESS

As part of the Rule 13-5 rule development process, staff has reached out to petroleum refinery industry experts and environmental advocacy and community groups. Staff conducted a briefing with the technical workgroup community members on June 27, 2019, to instruct them on the basic operations and primary processes of hydrogen plants, and thus, to better enable them to participate in technical workgroup discussions for the Rule 13-5 rule development project. Staff conducted the first refinery technical workgroup meeting on July 17, 2019 to discuss the availability and feasibility of all potential vented methane emission controls for hydrogen production equipment/processes. Staff submitted a comprehensive questionnaire to all hydrogen system operators requesting pertinent parametric and emissions data relating to all hydrogen venting occurrences during the past six years. The questionnaire was divided into two phases with a due date of November 18, 2019 for Phase I and a due date of January 10, 2020 for Phase II. In July and August of 2019, Rule development staff visited every hydrogen plant at each refinery for a total of 11 visits spread among the five refineries within the Air District's jurisdiction. Staff typically had pre-meetings with refinery staff, including hydrogen plant operators, conducted tours of the hydrogen plants and, when necessary, held post-tour meetings to ask more questions and clarify information. A second round of tours are in progress and will be concluded by the end of January 2020 to help staff identify plausible controls for each hydrogen system as each system is designed differently, and thus, may not use the same types of controls or install gas recovery systems in the same locations or with similar configurations.

REFERENCES

[a] https://www.energy.gov/eere/articles/hydrogen-clean-flexible-energy-carrier

[b] http://what-when-how.com/petroleum-refining/the-hydrotreating-process-part-1/

[c]https://www.digitalrefining.com/article/1000575,Hydrogen___the_key_refinery_enabler.html#.XaifCuhKgRk

[d] Compiled comments from representatives of several refineries and one independent third-party hydrogen plant operator during hydrogen plant tours by Air District staff in July 2019.

[e] BAAQMD Regulation 8, Rule 18: Equipment Leaks; http://www.baaqmd.gov/~/media/dotgov/files/rules/reg-8-rule-18-equipment-leaks/documents/rg0818.pdf?la=en

[f] http://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1189.pdf?sfvrsn=4

[g] Guha, A., Newman, S., Fairley, D., Dinh, T.H., Duca, L., Conley, S.C., Smith, M., Thorpe, A., Duren, R., Cusworth, D., Foster, K., Fischer M.L., and Martien, P.T., 2020, Assessment of regional methane emissions inventories through airborne quantification in the San Francisco bay area, in prep.

[h] Title 17, California Code of Regulations, section 95800 et seq.

[i] https://www.epa.gov/ghgreporting

[j] https://www.nature.com/articles/s41586-019-1720-3

[k] https://www.linde-engineering.com/en/images/HA_H_1_1_e_09_150dpi_NB_tcm19-6130.pdf